CLAIMS

1. An optical system comprising: a birefringent element for achieving a substantially circumferential distribution or a substantially radial distribution as a fast axis distribution in a lens aperture; and an optical rotator disposed behind the birefringent element and adapted to rotate a polarization state in the lens aperture.

2. The optical system according to Claim 1, wherein the birefringent element has an optically transparent member which is made of a uniaxial crystal material and a crystallographic axis of which is arranged substantially in parallel with an optical axis of the optical system, and

wherein a light beam of substantially spherical waves in a substantially circular polarization state is incident to the optically transparent member.

3. The optical system according to Claim 1, wherein the birefringent element has at least a pair of optically transparent members made of a crystal material of the cu

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4. The optical system according to Claim air of optically transparent members are arranged in a state in which a

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1. An optical system comprising: a birefringent element for achieving a substantially circumferential distribution or a substantially radial distribution as a fast axis distribution in a lens aperture; and an optical rotator disposed behind the birefringent element and adapted to rotate a polarization state in the lens aperture.

2. The optical system according to Claim 1, wherein the birefringent element has an optically transparent member which is made of a uniaxial crystal material and a crystallographic axis of which is arranged substantially in parallel with an optical axis of the optical system, and

wherein a light beam of substantially spherical waves in a substantially circular polarization state is incident to the optically transparent member.

3. The optical system according to Claim 1, wherein the birefringent element has at least a pair of optically transparent members made of a crystal material of the cubic system,

wherein the pair of optically transparent members are so positioned as to achieve a substantially circumferential distribution or a substantially radial distribution as a fast axis distribution in the lens aperture, and

wherein a light beam of substantially spherical waves in a substantially circular polarization state is incident to the pair of optically transparent members.

4. The optical system according to Claim 3, wherein the pair of optically transparent members are arranged in a state in which a

crystal orientation <111> is substantially parallel with an optical axis of the optical system and in which the other crystal orientations are relatively rotated by about 60° around the optical axis.

5. The optical system according to Claim 3, wherein the pair of optically transparent members are arranged in a state in which a crystal orientation <100> is substantially parallel with an optical axis of the optical system and in which the other crystal orientations are relatively rotated by about 45° around the optical axis.

6. The optical system according to Claim 1, wherein the birefringent element has an optically transparent member which is located near a pupil of the optical system and which has internal stress substantially with rotational symmetry with respect to an optical axis of the optical system, and

wherein a light beam in a substantially circular polarization state is incident to the optically transparent member.

7. The optical system according to any one of Claims 1 to 6, wherein the optical rotator is located at a position where a light beam is incident thereto with variation of not more than 10° in an angle of incidence.

8. The optical system according to any one of Claims 1 to 7, wherein the optical rotator rotates the polarization state in the lens aperture by about 45°.

9. The optical system according to any one of Claims 1 to 8, said optical system having a projection optical system for forming an image of a first surface on a second surface.

10. The optical system according to Claim 9, wherein the

projection optical system is arranged to be substantially telecentric on the first surface side, and

wherein the birefringent element is located in an optical path which is substantially telecentric on the first surface side.

11. The optical system according to any one of Claims 1 to 8, said optical system having an illumination optical system for illuminating a surface to be illuminated, in a substantially telecentric manner.

12. The optical system according to Claim 11, wherein the birefringent element is located at or near a position optically conjugate with the surface to be illuminated, in an optical path of the illumination optical system.

13. The optical system according to any one of Claims 1 to 8, said optical system having an illumination optical system for illuminating a first surface in a substantially telecentric manner; and a projection optical system for forming an image of the first surface on a second surface.

14. The optical system according to Claim 13, wherein the birefringent element is located in an optical path of the illumination optical system, and

wherein the optical rotator is located in an optical path of the projection optical system.

15. The optical system according to Claim 14, wherein the birefringent element is located near the first surface, or at or near a position optically conjugate with the first surface, in the optical path of the illumination optical system.

16. An optical system comprising:

a birefringent optical rotator which is made of an optical material with linear birefringence and optical rotatory power and an optic axis of which is arranged substantially in parallel with an optical axis of the optical system,

wherein a light beam in a substantially circular polarization state is incident to the birefringent optical rotator.

17. The optical system according to Claim 16, wherein the birefringent optical rotator is located at a position where a light beam of substantially spherical waves is incident thereto, and has a required thickness for converting a beam in a peripheral region of the incident light beam into a light beam in a substantially linear polarization state of substantially circumferential vibration in a lens aperture.

18. The optical system according to Claim 16 or 17, wherein the birefringent optical rotator has a first optically transparent member made of an optical material with clockwise optical rotatory power, and a second optically transparent member made of an optical material with counterclockwise optical rotatory power.

19. The optical system according to any one of Claims 16 to 18, said optical system having a projection optical system for forming an image of a first surface on a second surface.

20. The optical system according to Claim 19, wherein the projection optical system is arranged to be substantially telecentric on the first surface side, and

wherein the birefringent optical rotator is located in an optical path which is substantially telecentric on the first surface side.

21. The optical system according to Claim 19, wherein the projection optical system is arranged to be substantially telecentric on the second surface side, and

wherein the birefringent optical rotator is located in an optical path which is substantially telecentric on the second surface side.

22. The optical system according to any one of Claims 16 to 18, said optical system having an illumination optical system for illuminating a surface to be illuminated, in a substantially telecentric manner.

23. The optical system according to Claim 22, wherein the birefringent optical rotator is located near the surface to be illuminated, or at or near a position optically conjugate with the surface to be illuminated, in an optical path of the illumination optical system.

24. The optical system according to any one of Claims 11 to 15, 22, and 23, wherein the illumination optical system forms a secondary light source having a predetermined optical intensity distribution, on an illumination pupil plane, and

wherein the predetermined optical intensity distribution of the secondary light source is so set that an optical intensity in a pupil center region being a region on the illumination pupil and including an optical axis is smaller than an optical intensity in a region around the pupil center region.

25. The optical system according to Claim 24, wherein the predetermined optical intensity distribution of the secondary light source has an optical intensity distribution of an annular shape or multi-pole shape.

26. An exposure apparatus comprising the optical system as defined in any one of Claims 1 to 25, said exposure apparatus being adapted to effect exposure of a pattern of a mask on a photosensitive substrate through the optical system.

27. An exposure method of effecting exposure of a pattern to be transferred, on a photosensitive substrate through the optical system as defined in any one of Claims 1 to 25.

28. A device fabrication method of effecting exposure of a pattern to be transferred, on a photosensitive substrate through the optical system as defined in any one of Claims 1 to 25.

29. The optical system according to any one of Claims 1 to 25, said optical system being an optical system for lithography.